DECLARATION

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SEMICONDUCTOR DEVICE AND PROCESS FOR ITS FABRICATION

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[Document] Specification

[Title of the Invention] Semiconductor device and process for its fabrication

[what is claimed is]

1. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a water absorption rate of 1.5% by volume or less.

2. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a saturation moisture absorption of rate1.0% by volume or less.

3. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a residual volatile component in an amount not more than 3.0% by weight.

4. A semiconductor device comprising a semiconductor chip bonded

to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a surface energy of 40erg/cm^{2}or above.

5. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having, at the stage where said semiconductor chip has been bonded to the support member, a void volume of 10% or less in terms of voids present in said die-bonding material and at an interface between said die-bonding material and said support member.

6. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a peel strength of 0.5 Kgf/5 × 5 mm chip or above at the stage where said semiconductor chip has been bonded to the support member.

7. A semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material,

said semiconductor chip being sealed with a resin,

wherein

said die-bonding material is a filmy organic die-bonding material having a planar dimension equal to or less than the planar dimension of the semiconductor chip, and not protruding outward from the region of the semiconductor chip at the stage where the semiconductor chip has been bonded to the support member.

8. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having, a water absorption rate of 1.5% by volume or less.

9. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a saturation moisture absorption rate of 1.0% by volume or less.

10. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,

wherein;

said die-bonding material is a filmy organic die-bonding material having a residual volatile component in an amount not more than 3.0% by weight.

11. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,
wherein;

said die-bonding material is a filmy organic die-bonding material having a surface energy of 40 erg/cm^2 or above.

12. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,
wherein;

said die-bonding material is a filmy organic die-bonding material having, at the stage where the semiconductor chip has been bonded to the support member, a void volume of 10% or less in terms of voids present in said die-bonding material and at an interface between said die-bonding material and said support member.

13. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,
wherein;

said die-bonding material is a filmy organic die-bonding material

having a peel strength of 0.5 kgf/5 × 5 mm chip or above at the stage where the semiconductor chip has been bonded to the support member.

14. A process for fabricating a semiconductor device comprising a semiconductor chip bonded to a support member via a die-bonding material, said semiconductor chip being sealed with a resin,
wherein;

said die-bonding material is a filmy organic die-bonding material having a planar dimension not larger than the planar dimension of said semiconductor chip, and not protruding outward from the region of said semiconductor chip at the stage where the semiconductor chip has been bonded to the support member.

[Detailed Description of the Invention]

[The Field of the invention]

This invention relates to a semiconductor device having a support member such as a lead frame to which a semiconductor die or chip is attached using a die-bonding material and sealed (encapsulated) with resin, and a process for the fabrication of such a semiconductor device.

[Prior Art]

As a method by which semiconductor chips are attached to lead frames, a method has been used in which a die-bonding material is fed onto the lead frame and the semiconductor chip is bonded thereto.

Such a die-bonding material is known to include, e.g., Au-Si eutectics,

solders and resin pastes. Of these, Au-Si eutectics have problems in that they are expensive, have a high modulus of elasticity, and require vibration at the bonding portion. The solders have problems in that they can not withstand temperatures equal to or greater than their melting temperature and have a high modulus of elasticity.

As for the resin pastes, silver paste is the most commonly available. Compared with other materials, silver paste is inexpensive, has a high heat resistance reliability and has a low modulus of elasticity. Hence, they are most widely used as bonding materials for the lead frames of ICs and LSIs.

[Problems to be Solved by the Invention]

In recent years, there has been a rapid increase in demand for high-density packaging as electronic machinery has been made smaller in size and thickness. In semiconductor packaging, conventional pin insertion packaging has been replaced by surface packaging, which has become the prevailing packaging method suitable for high-density packaging.

In surface packaging, in order to directly solder leads to printed-wiring substrates, packaging is carried out by infrared reflowing, vapor phase reflowing or solder dipping while heating the whole package.

During this packaging, the whole package is exposed to high temperatures of 210°C to 260°C. Hence, any presence of moisture in the package causes explosive vaporization of the moisture to cause package cracks (hereinafter called "reflow cracks").

Such reflow cracks may cause a significant lowering of the reliability of semiconductor packages, bringing about a serious technical problem.

The mechanism by which reflow cracks ascribable to die-bonding

materials occur is as follows: During storage of semiconductor packages, (1) die-bonding materials absorb moisture, (2) this moisture is vaporized upon heating when packaged by reflowing and soldering, and (3) vapor pressure thus produced causes breaking or separation of the die-bonding material layers, so that (4) the reflow cracks occur.

While reflow crack resistance of sealing mediums has been improved, the reflow cracks ascribable to die-bonding materials provide a serious matter especially in thin-type packaging. Thus, it is strongly sought to improve the reflow crack resistance.

The silver paste, having been most commonly used, tends to cause reflow cracks because it has become difficult with the increase in size of chips to uniformly coat the silver paste on the whole surface requiring area and also because it is pasty itself and therefore tends to cause voids in bonding layers.

An object of the present invention is to provide a semiconductor device that employs a filmy organic die-bonding material, may cause no reflow cracks and has good reliability, and a process for its fabrication.

[Means to Solve the Problems]

In the present invention, a filmy organic die-bonding material is employed. The filmy organic die-bonding material is a filmy material formed chiefly of an organic material as exemplified by an epoxy resin, a silicone resin, an acrylic resin and a polyimide resin (which may include organic materials to which a metal filler or an inorganic filler has been added). The filmy organic die-bonding material is contact-bonded to the surface of the support member such as a lead frame in the state in which the former is heated, and then the semiconductor chip is superposed on the filmy organic

die-bonding material, followed by press bonding with heating. More specifically, a resin paste is formed into a film so that the die-bonding material can be uniformly attached to the bonding portion.

Fig. 1 illustrates an example of a process for fabricating the semiconductor device of the present invention.

The filmy organic die-bonding material 1, is cut in a prescribed size with a cutter 2 ((a) in Fig. 1).

The filmy organic die-bonding material 1 is press-bonded to a die pad 6 of a lead frame 5 on a heating platen 7 by a pressing element 4.((b) in Fig. 1). The press bonding may preferably be carried out under conditions of a temperature of from 100°C to 250°C, a press time of from 0.1 second to 20 seconds and a pressure of from 100 - 5000 g.

A semiconductor chip 8 is put on the filmy organic die-bonding material 1 stuck to the die pad 6, followed by heat pressed bonding (i.e., die bonding) ((c) in Fig. 1). The die bonding may preferably be carried out under conditions of a temperature of from 150°C to 350°C, a bonding time of from 0.1 second to 20 seconds and a pressure of from 10 to 3000g.

Then, the step of wire bonding ((d) in Fig. 1) follows, and the step of sealing the semiconductor chip with resin ((e) in Fig. 1) follows thereafter. Thus, the semiconductor device is produced. Reference numeral 9 denotes a sealing resin.

For example, the filmy organic die-bonding material of the present invention is prepared by dissolving or dispersing an organic material such as polyimide resin or epoxy resin and optionally an additive such as a metal filler in an organic solvent to obtain a coating varnish, coating this coating varnish on a carrier film such as biaxially stretched polypropylene film, followed by

evaporation of the solvent to form a filmy material, and peeling the filmy material from the carrier film.

The inventors of the present invention have discovered that the occurrence of reflow cracks in semiconductor device correlates with the physical properties or characteristics of the filmy organic die-bonding material, and have made detailed studies on the relationship between the occurrence of reflow cracks and the characteristics of the filmy organic die-bonding material. As a result, they have accomplished the present invention.

According to a first embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and sealed with resin, a filmy organic die-bonding material having a water absorption rate of 1.5% by volume or less is used as the die-bonding material.

According to a second embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having a saturation moisture absorption rate of 1.0% by volume or less is used as the die-bonding material.

According to a third embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having a residual volatile component in an amount not more than 3.0% by weight is used as the die-

bonding material.

According to a fourth embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having a surface energy of 40 erg/cm 2 or more is used as the die-bonding material.

According to a fifth embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having, at the stage where the semiconductor chip is bonded to the support member, a void volume of 10% or less in terms of voids present in the die-bonding material and at the interface between the die-bonding material and the support member is used as the die-bonding material.

According to a sixth embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having a peel strength of 0.5 Kgf/5 $\times$ 5 mm chip or above at the stage where the semiconductor chip is bonded to the support member is used as the die-bonding material.

According to a seventh embodiment of the present invention, the semiconductor device and the process for its fabrication are characterized in that, in the semiconductor device having a support member to which a

semiconductor chip is attached using a die-bonding material and then sealed with resin, a filmy organic die-bonding material having a planar dimension not larger than the planar dimension of the semiconductor chip, and not protruding outward from the semiconductor chip at the stage where the semiconductor chip is bonded to the support member is used as the die-bonding material.

[Embodiment]

The filmy organic die-bonding material used in the first embodiment of the present invention, having a water absorption rate of 1.5% by volume or less, the filmy organic die-bonding material used in the second embodiment of the present invention, having a saturation moisture absorption of 1.0% by volume or less, the filmy organic die-bonding material used in the fourth embodiment of the present invention, having a surface energy of 40erg/cm2 or more, and the filmy organic die-bonding material used in the sixth embodiment of the present invention, having a peel strength of 0.5 Kgf/5 × 5 mm chip or above at the stage where the semiconductor chip is bonded to the support member, can be produced by controlling the composition of the filmy organic die-bonding material, e.g., the structure of polymers such as polyimide and the content of fillers such as silver.

The filmy organic die-bonding material used in the third embodiment of the present invention, having a residual volatile component in an amount not more than 3.0% by weight, and the filmy organic die-bonding material used in the fifth embodiment of the present invention, having, at the stage where the semiconductor chip is bonded to the die-bonding material, a void volume of 10% or less in terms of voids present in the die-bonding material and at the

interface between the die-bonding material and the support member, can be produced by controlling the conditions for producing the filmy organic die-bonding material, e.g., drying temperature, drying time and so forth.

The semiconductor chip includes commonly available semiconductor chips of ICs, LSIs, VLSIs and so forth, any of which may be used. The support member includes lead frames having die pads, padless lead frames (LOC), ceramic wiring boards and glass-polyimide wiring boards, any of which may be used.

As the filmy organic die-bonding material, not only those having a single-layer structure but also those having a multi-layer structure may be used.

In the present invention, the filmy organic die-bonding material may simultaneously possess two or more physical properties or characteristics of those described above.

For example, physical properties or characteristics the filmy organic die-bonding material may preferably possesses simultaneously are as follows:

(1) A filmy organic die-bonding material having a saturation moisture absorption rate of 1.0% by volume or less and a residual volatile component in an amount not more than 3.0% by weight;

(2) A filmy organic die-bonding material having a saturation moisture absorption rate of 1.0% by volume or less, and a peel strength of 0.5 Kgf/5 × 5 mm chip or above at the stage where the semiconductor chip is bonded to the support member;

(3) A filmy organic die-bonding material having a residual volatile component in an amount not more than 3.0% by weight and a peel strength

of 0.5 Kgf/5 × 5 mm chip or above at the stage where the semiconductor chip is bonded to the support member; and

(4) A filmy organic die-bonding material having a saturation moisture absorption rate of 1.0% by volume or less, a residual volatile component in an amount not more than 3.0% by weight, and a peel strength of 0.5 Kgf/5 × 5 mm chip or above at the stage where the semiconductor chip is bonded to the support member.

In the present invention, the foregoing physical properties or characteristics of the filmy organic die-bonding material may be in any combination in accordance with the purposes for which it is used.

The above (1) to (4) filmy organic die-bonding materials or the filmy organic die-bonding materials having the above physical properties or characteristics in any other combinations may preferably be used as filmy organic die-bonding materials each having a planar dimension not larger than the planar dimension of the semiconductor chip, and not protruding outward from the region of the semiconductor chip at the stage where the semiconductor chip is bonded to the support member.

[Example]

-Example 1-

To 100 g of polyimide(polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 280 g of an organic solvent was added to make a solution. To the solution obtained, silver powder was added in a stated amount, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by drying in a dryer with internal air circulation to cause the solvent to evaporate and dry the varnish. Thus, filmy organic die-bonding materials having the composition and water absorption rate as shown in Table 1 were prepared.

The filmy organic die-bonding materials as shown in Table 1 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, given a load of 1000g, and a bonding time of 5 seconds, followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at 240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured according to the following expression to make an evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 1.

Table 1

No.	Composition of film: Polyimide	Ag content	Water absorption	Rate of occurrence of reflow cracks
		(wt.%)	(%)	(%)
1	Polyimide A	80	2.0	100
2	Polyimide B	80	1.9	100
3	Polyimide C	80	1.8	100
4	Polyimide D	52	1.5	0
5	Polyimide E	60	1.2	0
6	Polyimide E	0	1.0	0
7	Polyimide F	60	0.9	0
8	Polyimide F	0	0.8	0
9	Polyimide F	40	0.7	0
10	Polyimide F	80	0.4	0
Comparative Example:				
	Silver paste		1.7	100

(As the silver paste, EPINAL (trade name; available from Hitachi Chemical Co., Ltd.) was used.)

- Measurement of Water Absorption Rate-

A film with a size of 50 × 50 mm is used as a sample. The sample is dried at 120°C for 3 hours in a vacuum dryer, and then left to cool in a desiccator. Thereafter, the dried weight of the sample is measured and is regarded as M1. The sample is immersed in distilled water at room temperature for 24 hours, and then taken out. The surface of the sample is wiped with filter paper and its weight is immediately measured and is regarded as M2.

The water absorption rate is calculated according to the following:

[(M2-M1)/(M1/d)] × 100 = Water absorption rate (vol.%)

wherein d is the density of the filmy organic die-bonding material.

Example 2

To 100 g of polyimide (polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 280 g of an organic solvent was added to make a solution. To the solution obtained, a predetermined amount of silver powder was added, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by drying in a dryer with internal air circulation to cause the solvent to evaporate and dry the varnish Thus, filmy organic die-bonding materials having the composition and saturation moisture absorption as shown in Table 2 were prepared.

The filmy organic die-bonding materials as shown in Table 2 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, given a load of 1000g and a bonding time of 5 seconds, followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at

240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured according to the following expression to make evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 2.

Table 2

No.	Composition of film: Polyimide	Composition of film: Ag content (wt.%)	Saturation moisture absorption (%)	Rate of occurrence of reflow cracks (%)
1	Polyimide A	80	1.7	100
2	Polyimide B	80	1.5	100
3	Polyimide C	80	1.4	100
4	Polyimide D	80	1.0	0
5	Polyimide D	60	0.8	0
6	Polyimide D	40	0.6	0
7	Polyimide F	0	0.5	0
8	Polyimide F	60	0.4	0
9	Polyimide F	52	0.3	0
10	Polyimide F	40	0.2	0
Comparative Example:				
	Silver paste		1.2	100

(As the silver paste, EPINAL (trade name; available from Hitachi Chemical

Co., Ltd.) was used.)

- Measurement of Saturation Moisture Absorption Rate-

A circular filmy organic die-bonding material of 10 mm diameter is used as a sample. The sample is dried at 120°C for 3 hours in a vacuum dryer, and then left to cool in a desiccator. Thereafter, the dried weight of the sample is measured and is regard as M1. The sample is moisture-absorbed in a thermo-hygrostat of 85°C and 85%RH, and then taken out. Its weight is immediately measured until the values of weight become constant. This weight is regarded as M2.

The saturation moisture absorption is calculated according to the following:

$$[(M2-M1)/(M1/d)] \times 100 = \text{saturation moisture absorption rate (vol.\%)}$$

wherein d is the density of the filmy organic die-bonding material.

<u>Example 3</u>

To 100 g of polyimide (polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 140 g of dimethylacetamide and 140 g of cyclohexanone were added as solvents to make a solution. To the solution obtained, 74 g of silver powder was added, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by heating at temperatures of from 80°C to 120°C in a dryer with internal air circulation to cause the solvent to evaporate and dry the vanish. Thus, filmy organic die-bonding materials having the

residual volatile component as shown in Table 3 were prepared. Here, when the drying temperature was higher than 120°C, the coating was dried on the OPP film at 80°C for 30 minutes, and thereafter the resulting filmy organic die-bonding material was peeled from the OPP film, which was then held on an iron frame, and again heated in the dryer to dry it.

The filmy organic die-bonding materials as shown in Table 3 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, given a load of 1000g and a bonding time of 5 second, followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at 240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured according to the following expression to make evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 3.

Table 3

No.	Drying temp.	Drying time	Residual volatile component	Voids in film	Rate of occurrence of reflow cracks
	(C°)	(min)	(wt.%)		(%)
1	80	30	6.5	Present	100
2	100	2	4.9	Present	100
3	100	4	4.2	Present	100
4	100	10	3.8	Present	80
5	100	30	3.5	Present	60
6	120	10	2.9	None	0
7	120	75	2.2	None	0
8	140	10	2.0	None	0
9	160	10	1.5	None	0
10	140	60	1.2	None	0
11	160	30	0.7	None	0
Comparative Example:					
	Silver paste		15.0	Present	100

(As the silver paste, EPINAL (trade name; available from Hitachi Chemical Co., Ltd.) was used.)

- Measurement of Residual Volatile Component -

A filmy organic die-bonding material with a size of 50 × 50 mm is used as a sample. The weight of the sample is measured and is regarded as M1. The sample is heated at 200°C for 2 hours in a hygrostat with internal air circulation, and thereafter its weight is immediately measured and is regarded

as M2.

The residual volatile component is calculated according to the following:

$$[(M2-M1)/M1] \times 100 = \text{residual volatile component (wt.\%)}$$

Example 4

To 100 g of polyimide (polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 280 g of organic solvent were added to make a solution. To the solution obtained, a predetermined amount of silver powder was added, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by heating in a dryer with internal air circulation to cause the solvent to evaporate and dry the varnish. Thus, filmy organic die-bonding materials having the composition and the surface energy as shown in Table 4 were prepared.

The filmy organic die-bonding materials as shown in Table 4 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, given a load of 1000g and a bonding time of 5 seconds, followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at 240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured according to the following expression to make an evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 4.

Table 4

No.	Composition of film: Polyimide	Composition of film: Ag content (wt.%)	Surface Energy (%)	Rate of occurrence of reflow cracks (%)
1	Polyimide D	85	39	100
2	Polyimide B	80	38	100
3	Polyimide D	80	41	100
4	Polyimide F	80	42	0
5	Polyimide F	60	43	0
6	Polyimide F	40	44	0
7	Polyimide F	0	45	0
Comparative Example:				
	Silver paste		37	100

(As the silver paste, EPINAL (trade name; available from Hitachi Chemical

Co., Ltd.) was used.)

- Measurement of Surface Energy -

A contact angle of water and diiodomethane with respect to the surface of the filmy organic die-bonding material was measured using a contact angle measurement. Based on the contact angle of water and diiodomethane thus measured, the surface energy was calculated according to the expression as shown in Figure 2, using the geometrical means method.

<u>Example 5</u>

To 100 g of polyimide (polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 140 g of dimethylacetamide and 140 g of cyclohexanone were added as solvents to make a solution. To the solution obtained, 74 g of silver powder was added, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by heating at temperatures of from 80°C to 120°C in a dryer with internal air circulation to cause the solvent to evaporate and dry the varnish. Thus, filmy organic die-bonding materials having the void volume as shown in Table 5 were prepared. Here, when the drying temperature was higher than 120°C, the coating was dried on the OPP film at 80°C for 30 minutes, and thereafter the resulting filmy organic die-bonding material was peeled from the OPP film, which was then held on an iron frame, and again heated in the dryer to dry it.

Herein, the void volume refers to a void volume in terms of voids

present in the die-bonding material and at the interface between the die-bonding material and the support member at the stage where the semiconductor chip is bonded to the support member.

The filmy organic die-bonding materials as shown in Table 4 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, a given load of 1000g and a bonding time of 5 seconds, followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at 240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured according to the following expression to make an evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 5.

Table 5

No.	Drying temp. (C°)	Drying time (min)	Void volume (wt.%)	Rate of occurrence of reflow cracks (%)
1	80	30	30	100
2	100	2	22	100
3	100	10	17	80
4	120	10	10	0
5	120	75	7	0
6	140	10	5	0
7	160	30	0	0
Comparative Example:				
Silver paste			40	100

* As the silver paste, EPINAL (trade name; available from Hitachi Chemical Co., Ltd.) was used.

Method of measurement of void volume

A silicone chip is bonded to a lead frame using the filmy organic die-bonding material to make a sample. A photograph of a top view of the sample is taken using a soft X-ray device. The area percentage of voids in the photograph is measured using an image analyzer, and the area percentage of the voids seen through the sample from its top is regarded as the void volume (%).

[Example 6]

To 100 g of polyimide (polyimide prepared by synthesizing bistrimellitate type anhydride and aromatic diamine) produced by Hitachi Chemical Co., Ltd, and 10 g of epoxy resin, 280 g of an organic solvent was

added to make a solution. To the solution obtained, silver powder was added in a stated amount, followed by thorough stirring so as to be uniformly dispersed, to obtain a coating varnish.

This coating varnish was coated on a carrier film (OPP film; biaxially stretched polypropylene), followed by drying in a dryer with internal air circulation to cause the solvent to evaporate and dry the varnish. Thus, filmy organic die-bonding materials having the composition and peel strength as shown in Table 6 were prepared.

Herein, the peel strength refers to the peel strength of the filmy organic die-bonding material at the stage where the semiconductor chip is bonded to the support member through the filmy organic die-bonding material.

The filmy organic die-bonding materials as shown in Table 6 were each stuck onto the tab of the lead frame while heating at 160°C. On the lead frame to which the filmy organic die-bonding material was thus stuck, a semiconductor chip was mounted by die bonding carried out under conditions of a temperature of 300°C, a given load of 1000g and a bonding time of 5 seconds followed by wire bonding and then molding with a sealing medium (trade name CEL-9000, available from Hitachi Chemical Co., Ltd.). Thus, a semiconductor device was fabricated (QFP package: 14 × 20 × 1.4 mm; chip size: 8 × 10 mm; 42 alloy lead frame).

The semiconductor device having been thus sealed was treated in a thermo-hygrostat of 85°C and 85%RH for 168 hours, and thereafter heated at 240°C for 10 seconds in an IR reflow furnace.

Thereafter, the semiconductor device was molded with polyester resin, and then cut with a diamond cutter to observe its cross section on a microscope. Rate (%) of occurrence of reflow cracks was measured

according to the following expression to make an evaluation on the reflow crack resistance.

(Number of occurrences of reflow cracks/number of tests) × 100 = rate (%) of occurrence of reflow cracks.

The results of evaluation are shown in Table 6.

Table 6

No.	Composition of film: Polyimide	Composition of film: Ag content (wt.%)	Peel strength (Kgf/ 5 × 5 mm chip)	Rate of occurrence of reflow cracks (%)
1	Polyimide B	80	0.2	100
2	Polyimide C	80	0.3	100
3	Polyimide A	80	0.4	80
4	Polyimide D	80	0.5	0
5	Polyimide F	80	0.7	0
6	Polyimide F	0	0.8	0
7	Polyimide F	30	1.0	0
8	Polyimide F	20	1.5	0
9	Polyimide F	40	>2.0	0
10	Polyimide F	52	>2.0	0

Table 6

No.	Film size (mm)	Planar dimension of film (mm²)	Chip size (mm)	Planar dimension of chip	Outward protrusion	Rate of occurrence of reflow cracks (%)
1	11×13	143	8×10	80	Yes	100
2	10×12	123	8×10	80	Yes	100
3	9×11	99	8×10	80	Yes	100
4	9×10	90	8×10	80	Yes	70
5	8×11	88	8×10	80	Yes	60
6	8×10	80	8×10	80	No	0
7	8×9	72	8×10	80	No	0
8	7×10	70	8×10	80	No	0
9	8×9	72	8×10	80	No	0
10	6×8	48	8×10	80	No	0
11	5×7	35	8×10	80	No	0
12	4×6	24	8×10	80	No	0
13	3×5	15	8×10	80	No	0
14	2×4	8	8×10	80	No	0

[Effect of the invention]

As described above, the semiconductor device of the present invention can be free from the occurrence of reflow cracks during reflow soldering for the packaging of semiconductor devices, promising good reliability.

[Brief description of the Drawings]

[Fig. 1] Cross-sectional illustration of an example of a process for fabricating the semiconductor device of the present invention.

[Fig. 2] An expression by which the surface energy is calculated.

[Fig. 3] A front elevation used to describe a method for measuring peel strength by using a push-pull gauge.

[Explanation of reference numerals]

1. filmy organic die-bonding material
2. cutter
3. guide roll
4. pressing element
5. lead frame
6. die pad 6
7. heating platen
8. semiconductor chip
9. sealing resin

21. semiconductor chip
22. filmy organic bonding material
23. lead frame
24. push-pull gauge
25. heating platen